Technology: Changing the Game
- Impacts of Technological Changes in the Cyber Environment on Software/Systems Engineering Workforce Development

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Theme: Technology : Changing the Game

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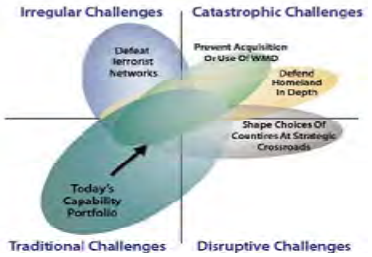
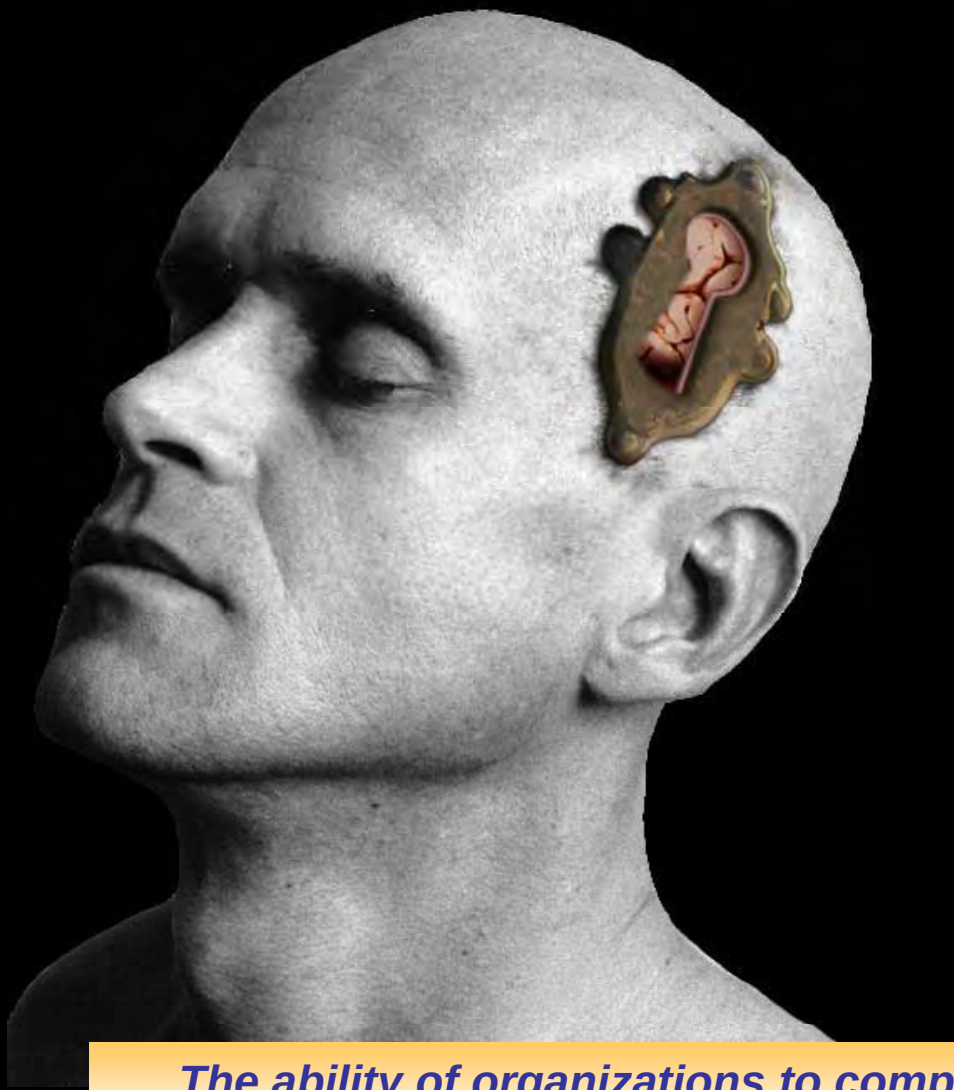
Overview



- Perspective
- The Problem Space
- Software and Systems Engineering Issues
- The Human Element

Human Element



The ability of organizations to compete will increasing depend on the innovation of the human element

Cyber Security Landscape

Stakeholders recognize the importance of cyber infrastructure to our nation's prosperity.

- Public and private sector enterprises today are *highly dependent* on information systems to carry out their missions and business functions.
  - To achieve mission and business success, enterprise information systems must be *dependable* in the face of serious cyber threats.
- To achieve information system dependability, the systems must be appropriately *protected*.

Source: "Information Systems Under Attack", NIST

"…I'll make cyber security the top priority that it should be in the 21st century… coordinate efforts across the federal government, implement a truly national cyber-security policy, and tighten standards to secure information..."

President Barack Obama

What is at risk?

Transportation Infrastructure

+

Healthcare Infrastructure

+

Banking & Financial Infrastructure

+

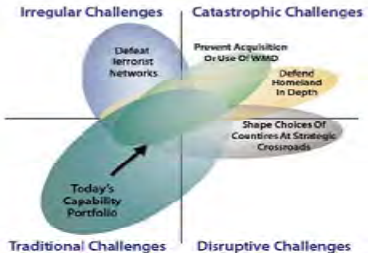
Energy & Utilities Infrastructure

+

Communications Infrastructure

...

Overview



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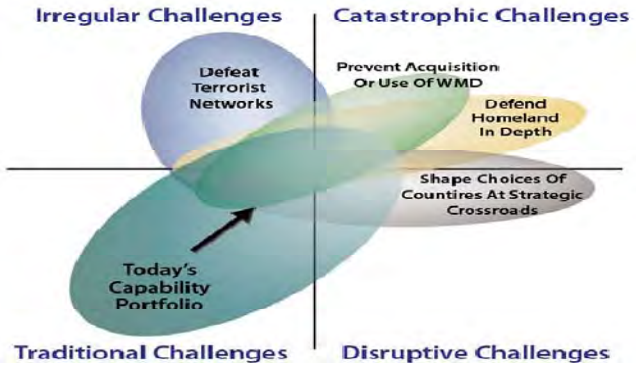
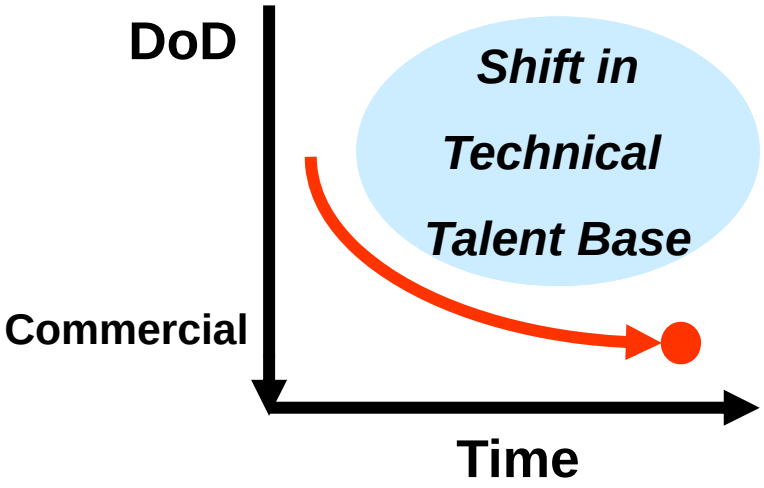
Imperatives

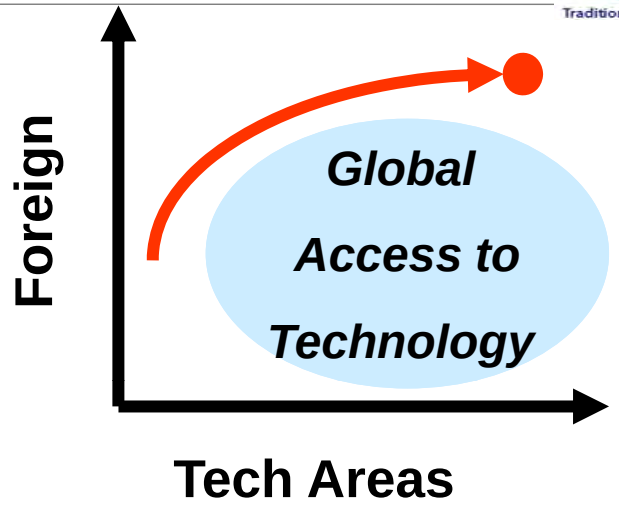


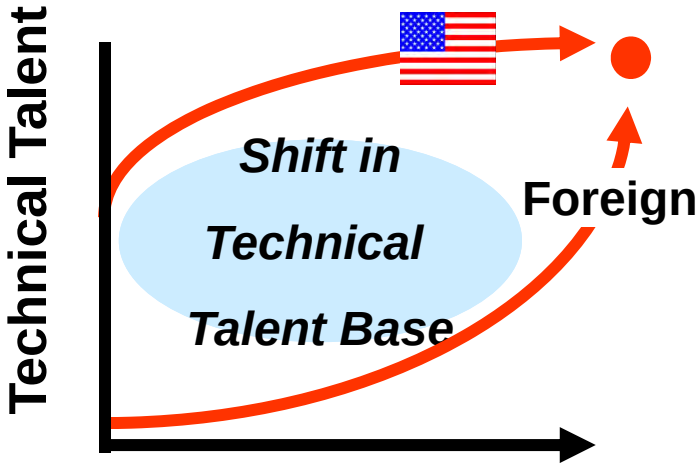
- **DDR&E Imperatives***
  - Accelerate delivery
  - Uncertain future
  - Reduce the cost, acquisition time and risk
  - Develop world class STEM **

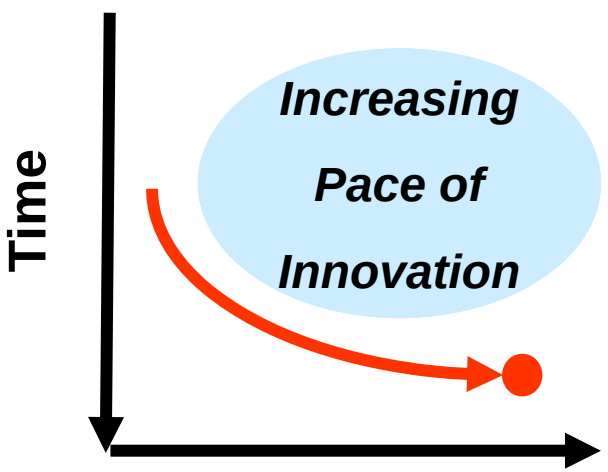
* The Honorable Zachary J. Lemnios, DDR&E
** Science, Technology, Engineering and Mathematics Capabilities

Four Key Challenges to our Technical Base









Source: DDR&E

DON Systems Engineering Hierarchy

Mission
Force Focus

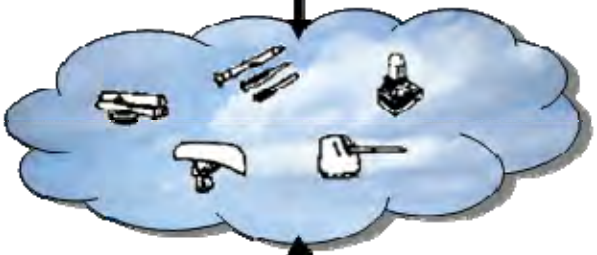
Translates
Operational Concepts → Mission Capabilities

SoS
Platform / Net Centric
Capability Focus

Translates
Mission Capabilities → System Requirements

System
Functional Focus

Translates
System Requirements → Component Functions

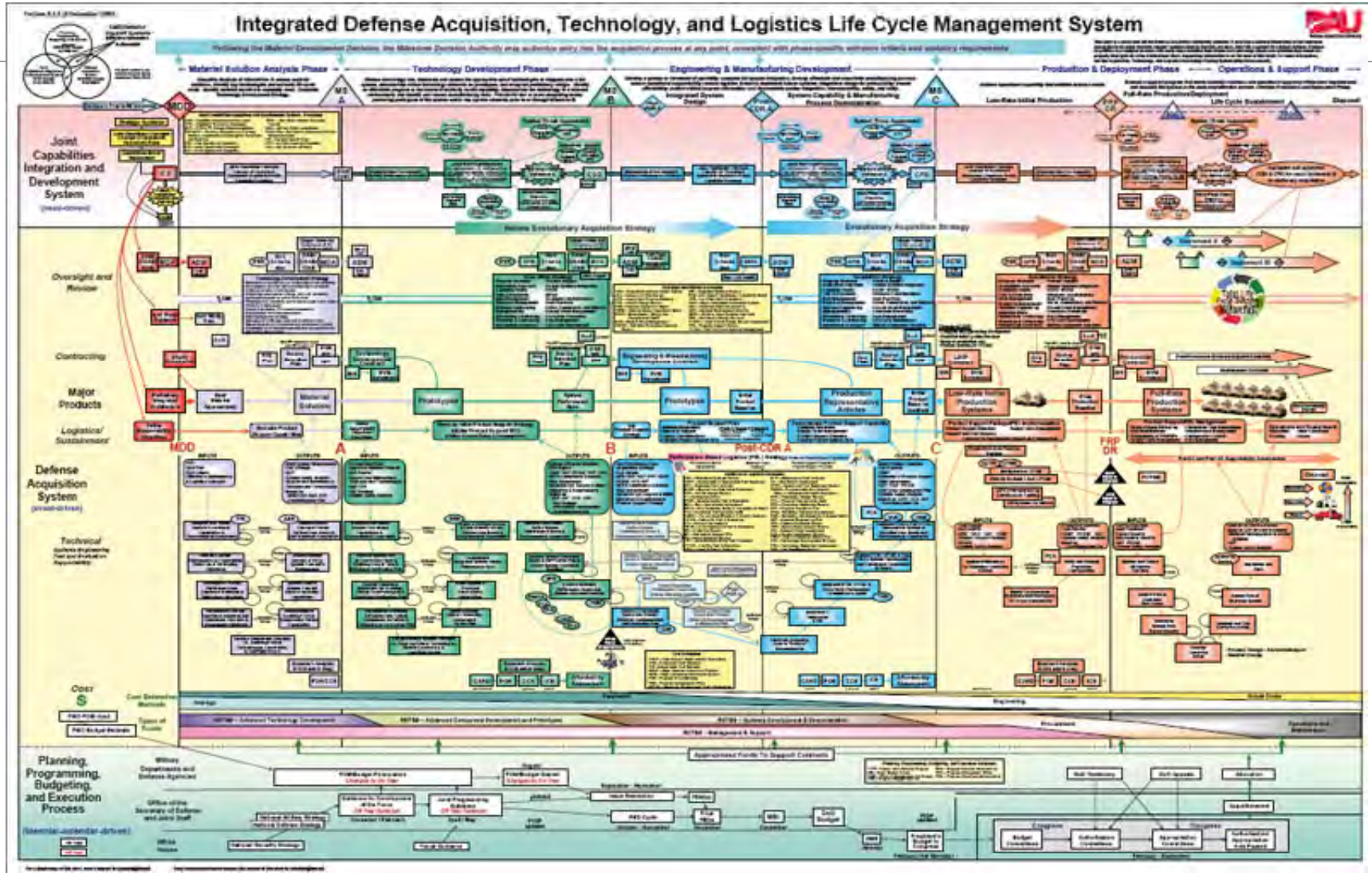


Component
End Item Focus

Translates
Component Functions → End Items

DON = Department of Navy

An Effective Process for Major Defense Systems – But Not Very Agile



Defense Acquisition Approach - Systems Engineering is Key Discipline

5 to 15 Years

Concept Engineering
- Intel review
- Op needs
- Tech objectives
- SCR

MDD

Material Solution Analysis
- DP/Early SE
- AoA
- Red Taming
- SEP
- T&E Strategy

MS A

Technology Development
- Threat assess
- System Spec
- SEP
- T&E plan
- SRR & PDR
- Prototype dev
- TRA

MS B

Engineering & Manufacturing Development
- CDR
- TRR
- Dev test & eval
- Initial Ops Test & Eval
- PRR
- TRA Update

MS C

Production & Deployment

LRIP | FRP
- Transition
- Ops Test & Eval
- Training

Operations
- Sustainment
- Disposal

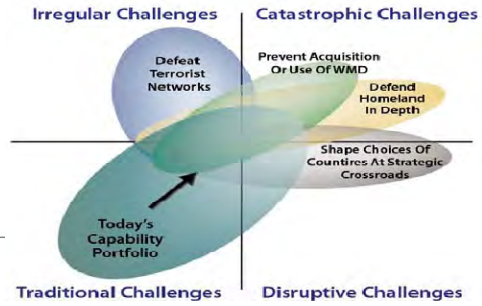
Technology and Risk Reduction
- Technology "push" investment
- Technology maturation
- Phenomenology measurements

70-75% of Cost Decisions Made Prior to Milestone A
Impact 72% of Total Life Cycle Costs

AoA – Assessment of Alternatives
DP – Developmental Planning
MDD – Material Development Decision
SCR – System Concept Review
SRR – System Requirements Review
SEP – System Engineering Plan
PDR – Preliminary Design Review
CDR – Critical Design Review
TRR – Test Readiness Review
PRR – Production Readiness Review
LRIP – Low-Rate Initial Production
FRP – Full Rate Production

Source: DDR&E

Need for Space, Air, Ground, Water, Underwater Software-Intensive Systems that are Interconnected

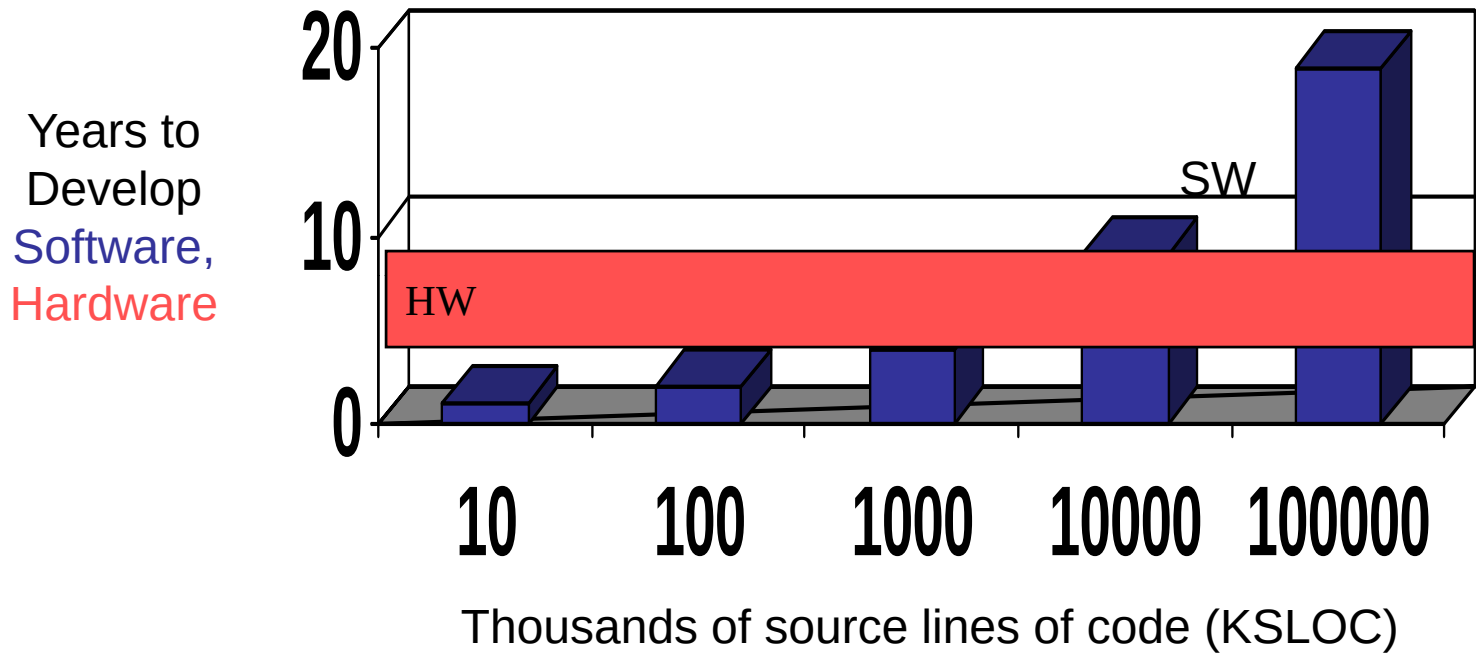


- Several million SLOC programs; "Hybrid" systems combining legacy re-use, COTS, new development
- Multi-contractor teams using different processes; dispersed engineering, development & operational locations
- New technologies create opportunities/challenges; products change/evolve, corporations mutate
- Business/operational needs change - often faster than full system capability can be implemented
- Skillset Shortfalls; Cost and schedule constraints
- Demands for increased integration, interoperability, system of system capabilities
- Enterprise perspectives/requirements; sustainment concerns

Development Complexity of Software-Intensive Systems is Increasing

Software Development Schedule Trends

#Years ~ 0.4 * cube root (KSLOC)



- Delaying software start increasingly risky
- Need to find ways to compress software schedules
- - Timeboxing; architecting for decoupled parallel development

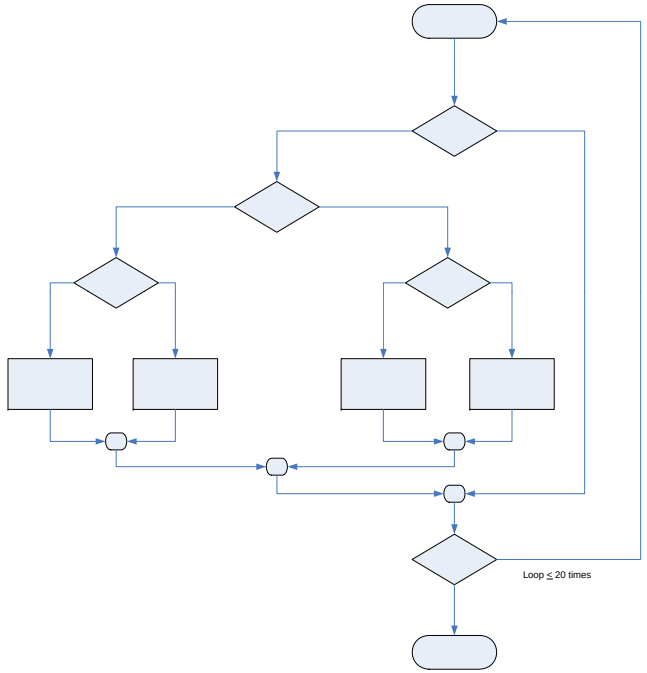
Ref: Barry Boehm

Realities of Software Quality

The flowchart might correspond to a 100 LOC module with a single loop that may be executed no more than 20 times.

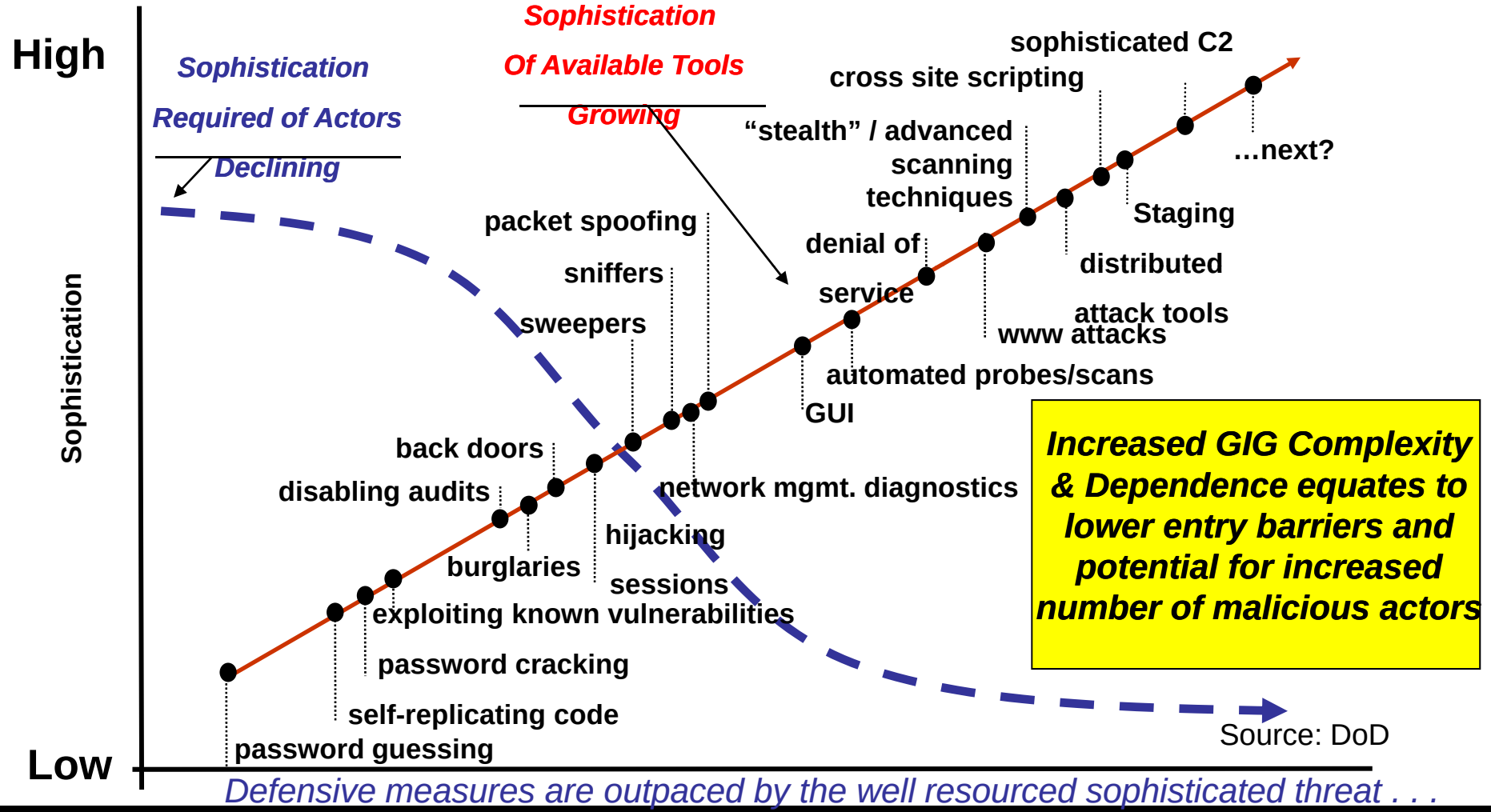
There are approximately 10^{14} possible paths that may be executed!

For any but the smallest programs, complete path coverage for defect detection is impractical.



Adapted from Pressman, R.S., *Software Engineering: A Practitioner's Approach, Third Edition*, McGraw Hil, 1992

Technological: Rate of Adoption
The Cyber Domain is Hotly Contested



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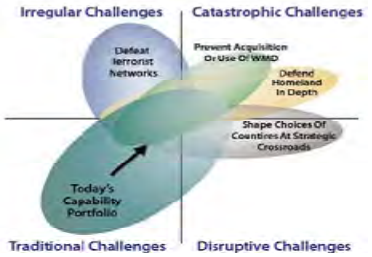

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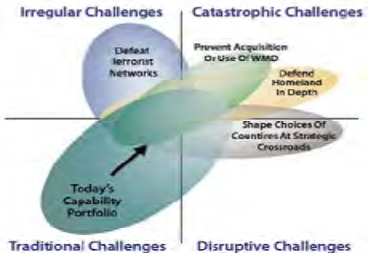
Top System Engineering Issues - 2010

- Increasingly, urgent demands of the warfighter are requiring effective capabilities to be fielded more rapidly than the conventional acquisition processes and development methodologies allow.
- The quantity and quality of Systems Engineering expertise is insufficient to meet the demands of the government and defense industry
- Systems engineering practices known to be effective are not consistently applied or properly resourced to enable early system definition
- Technical decision makers do not have the right information & insight at the right time to support informed & proactive decision making to ensure effective & efficient program planning, management & execution.
- The development of systems with a full level of integrity (all technical aspects considered) is longer and more expensive over the entire lifecycle as the technical solution is iterated and reworked in later stages of the development.

Top Software Engineering Issues - 2010

- The increasing demands of the war fighter are requiring development of software and systems more rapidly than acquisition models and development processes allow.
- Inadequate/insufficient program planning and start-up has a negative exponential impact on the program's software success.
- For complex systems and systems-of-systems, software engineering practices are not well defined
- There is insufficient attention given to the overall software life cycle activities including sustainment and changing threats
- Fundamental system engineering decisions are made without full participation of software engineering (2006 carry over)
  - Education programs do not adequately address need for software engineering to be involved throughout the acquisition process.

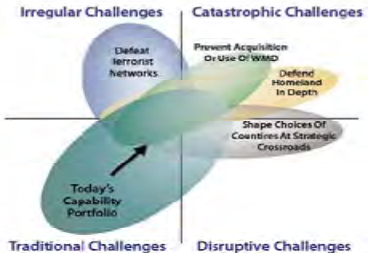
Software Engineering Trends



- Software engineering will become increasing vital to DoD, government, and commercial operations.
- Software will become increasing complex and connected.
- New technical, governance, and process concepts are needed to handle increasing complexity and decentralization.
- Software and systems engineering architectures are vital to the development, evolution and sustainment of future systems.
- Increasing complex and connected systems need to be architected for security and for operational resiliency.

Source: SEI

What Makes Software Engineering Different?

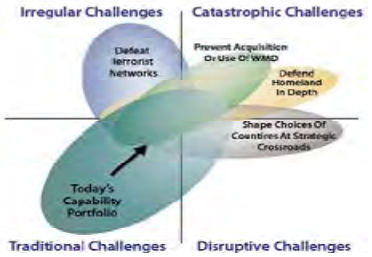


- Essential Properties of Software differentiate it from other kinds of engineering artifacts
  - Software Invisibility
    - No physical properties
  - Complexity
    - Effort/expense required to construct it for their size
  - Conformity
    - Must conform to exacting specifications
  - Software Changeability
    - Most frequently changed element

Cyber Engineering Compared with other Sciences

	PHYSICAL SCIENCE	BIOSCIENCE	SOFTWARE/CYBER ENGINEERING
Origins/History	Begun in antiquity	Begun in antiquity	Mid-20th Century
Enduring Laws	Laws are foundational to furthering exploration in the science	Laws are foundational to furthering exploration in the science	Only mathematical laws have proven foundational to computation
Framework of Scientific Study	Four main areas: astronomy, physics, chemistry, and earth sciences	Science of dealing with health maintenance and disease prevention/treatment	• Several areas of study: computer science, software/ systems engineering, IT, HCI, social dynamics, AI • All nodes attached to/relying on netted system
R&D and Launch Cycle	10-20 years	10-20 years	Significantly **compressed**; solution time to market needs to happen very quickly

Overview



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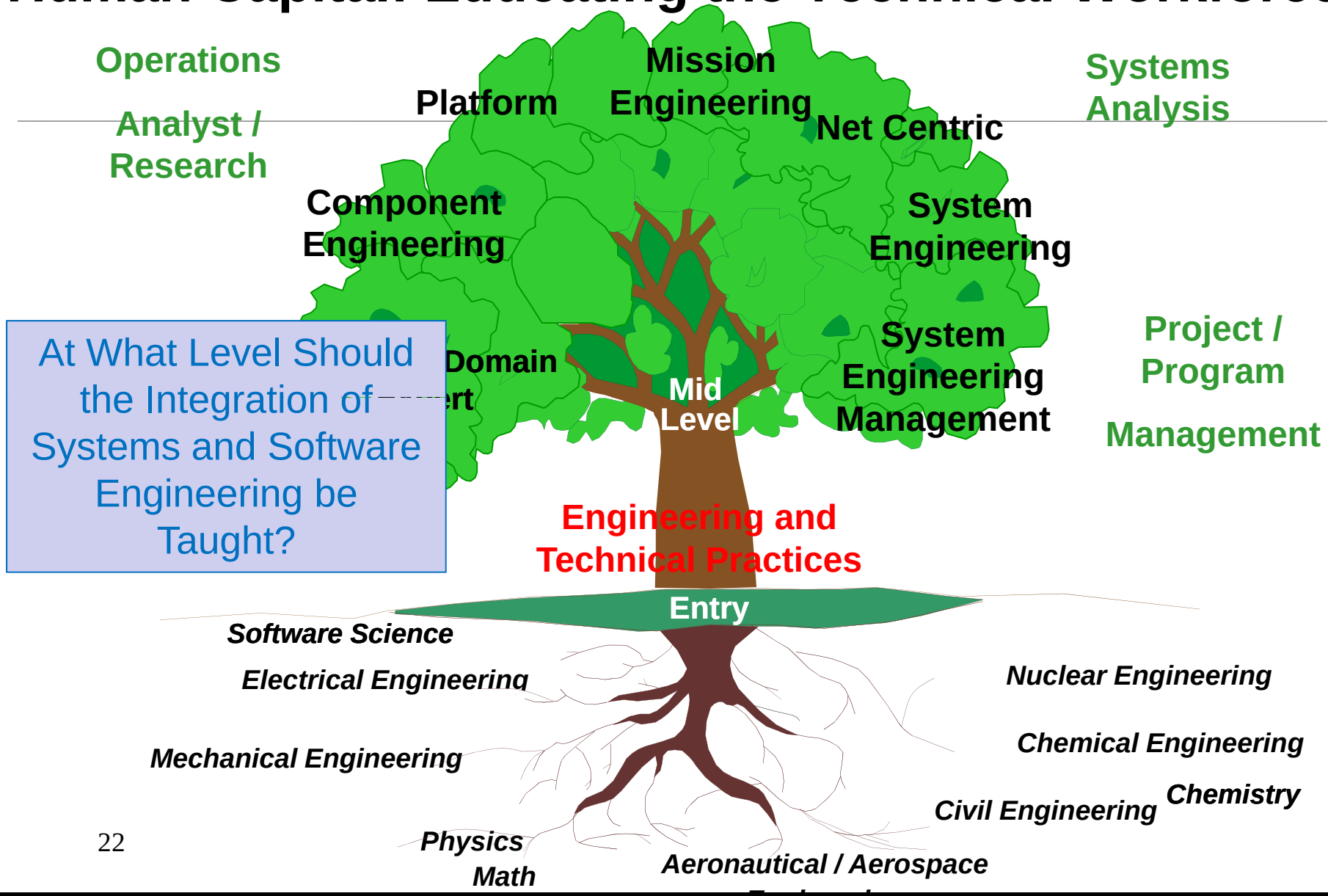
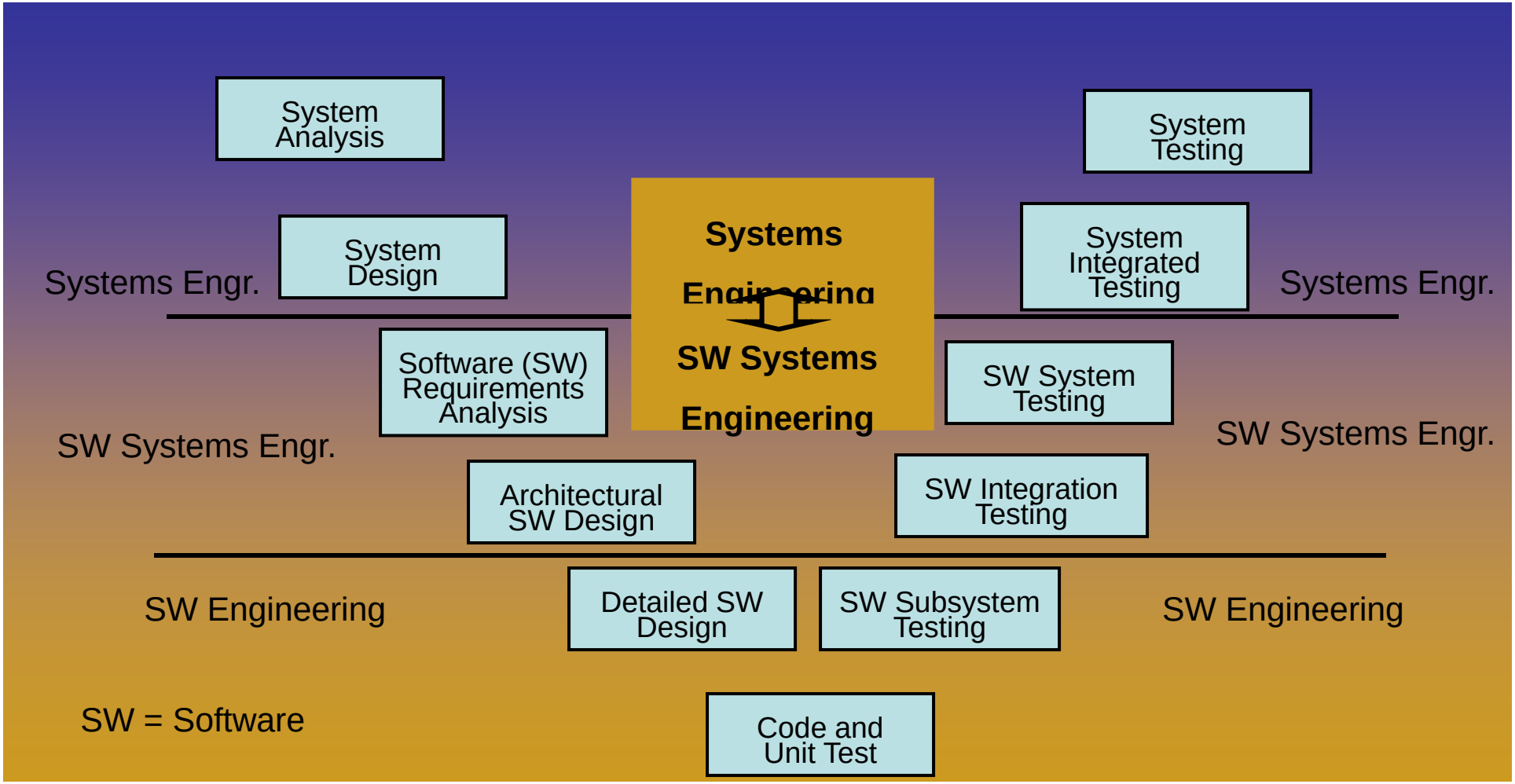
Human Capital: Educating the Technical Workforce



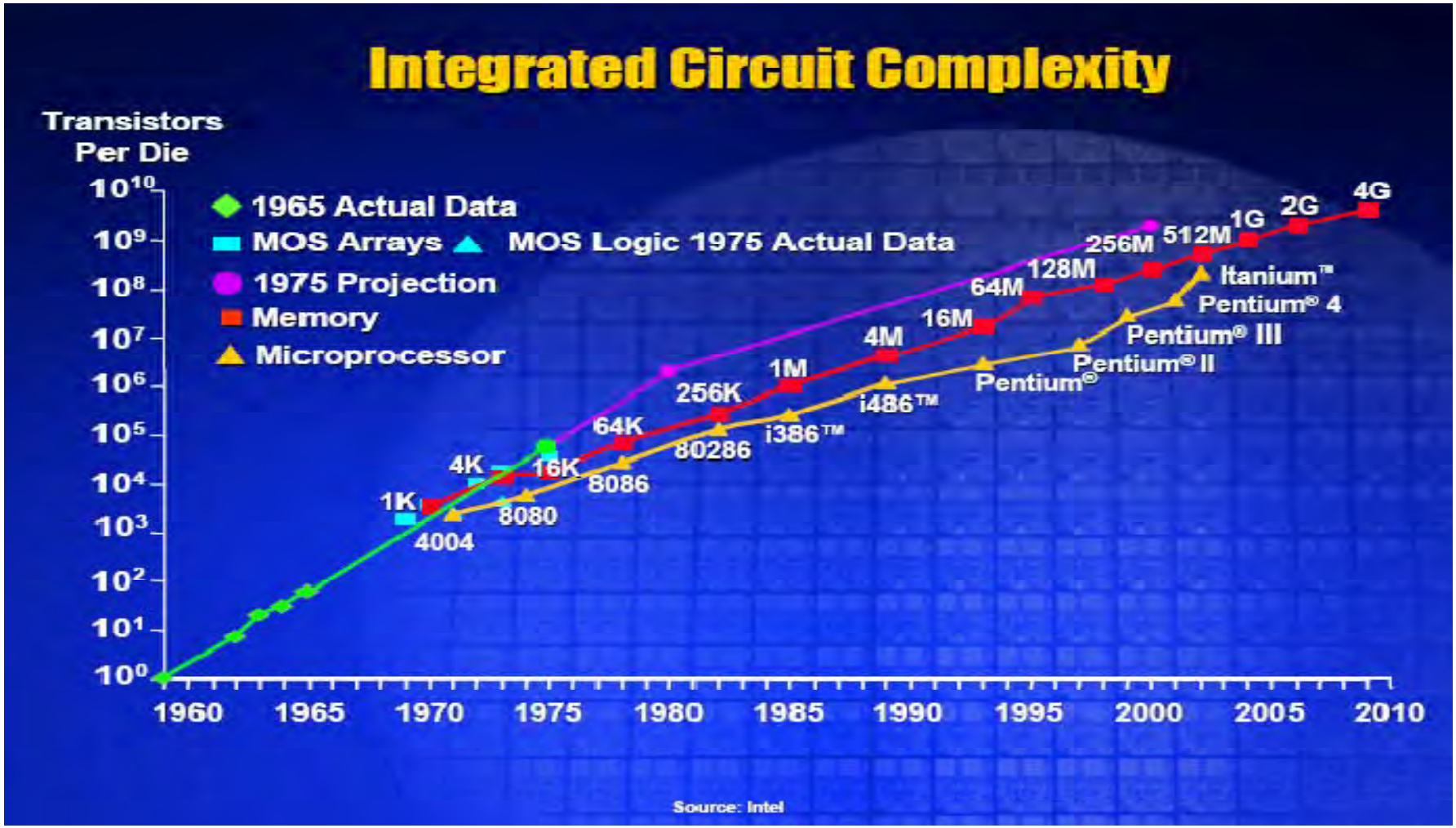
Refocusing University Curriculums: Alignment of Software and Systems Engineering



OSD Initiatives: Graduate Software Engineering Reference Curriculum (GSwERC)

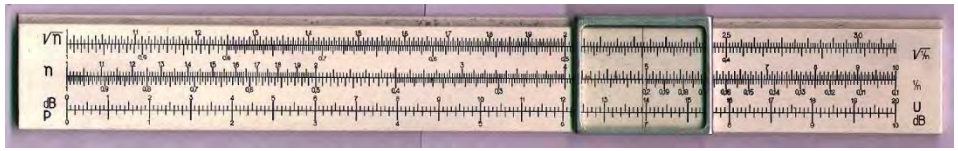
& Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE)

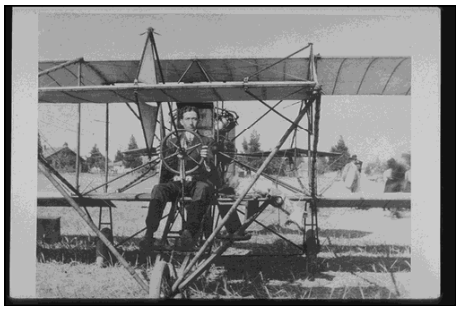
Moore's Law: The Number of Transistors That Can be Placed on an Integrated Circuit is Doubling Approximately Every Two Years



Augustine′s Law: Growth of Software - Order of Magnitude Every 10 Years

In The Beginning





1960's

F-4A
1000
LOC

1970's

F-15A
50,000
LOC

1980's

F-16C
300K
LOC

1990's

F-22
1.7M
LOC

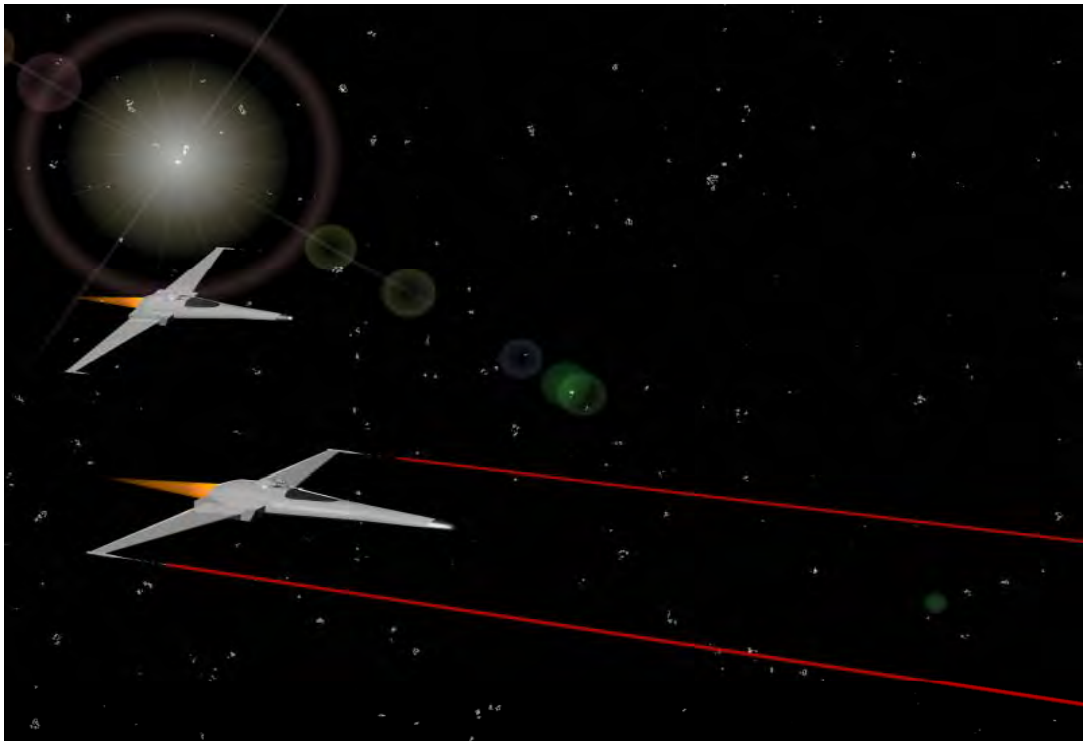
2000+

F-35
>6M
LOC

Trend & Implications: Augustine's Law Will Hold

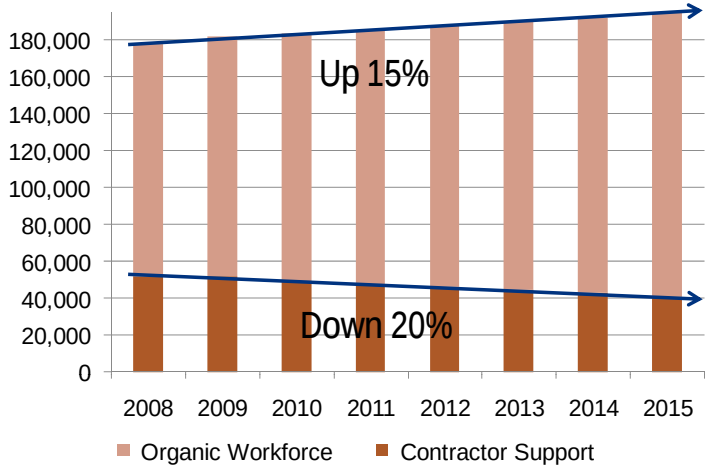
2080?

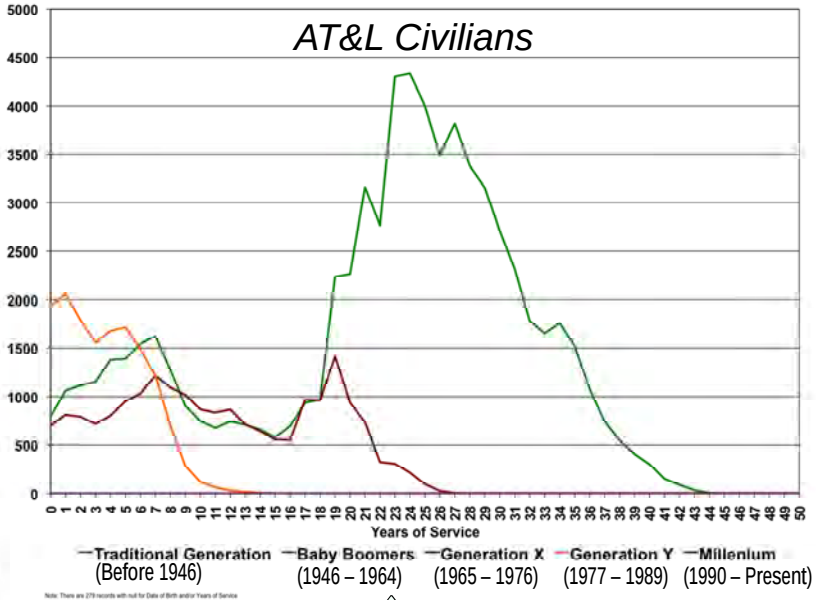
F-50 - 4.7B Lines of Code

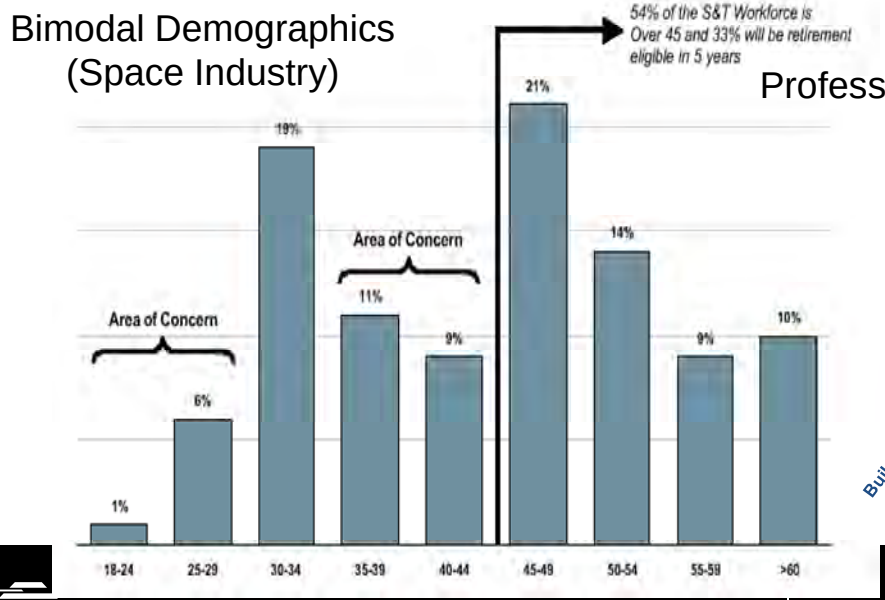


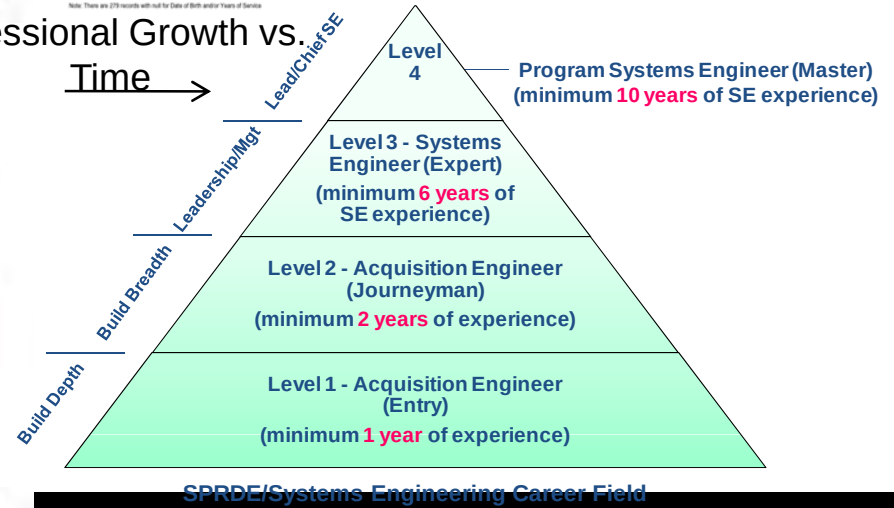
Need for increased functionality will be a forcing function to bring the fields of software and systems engineering closer together

Human Capital: Society Drivers









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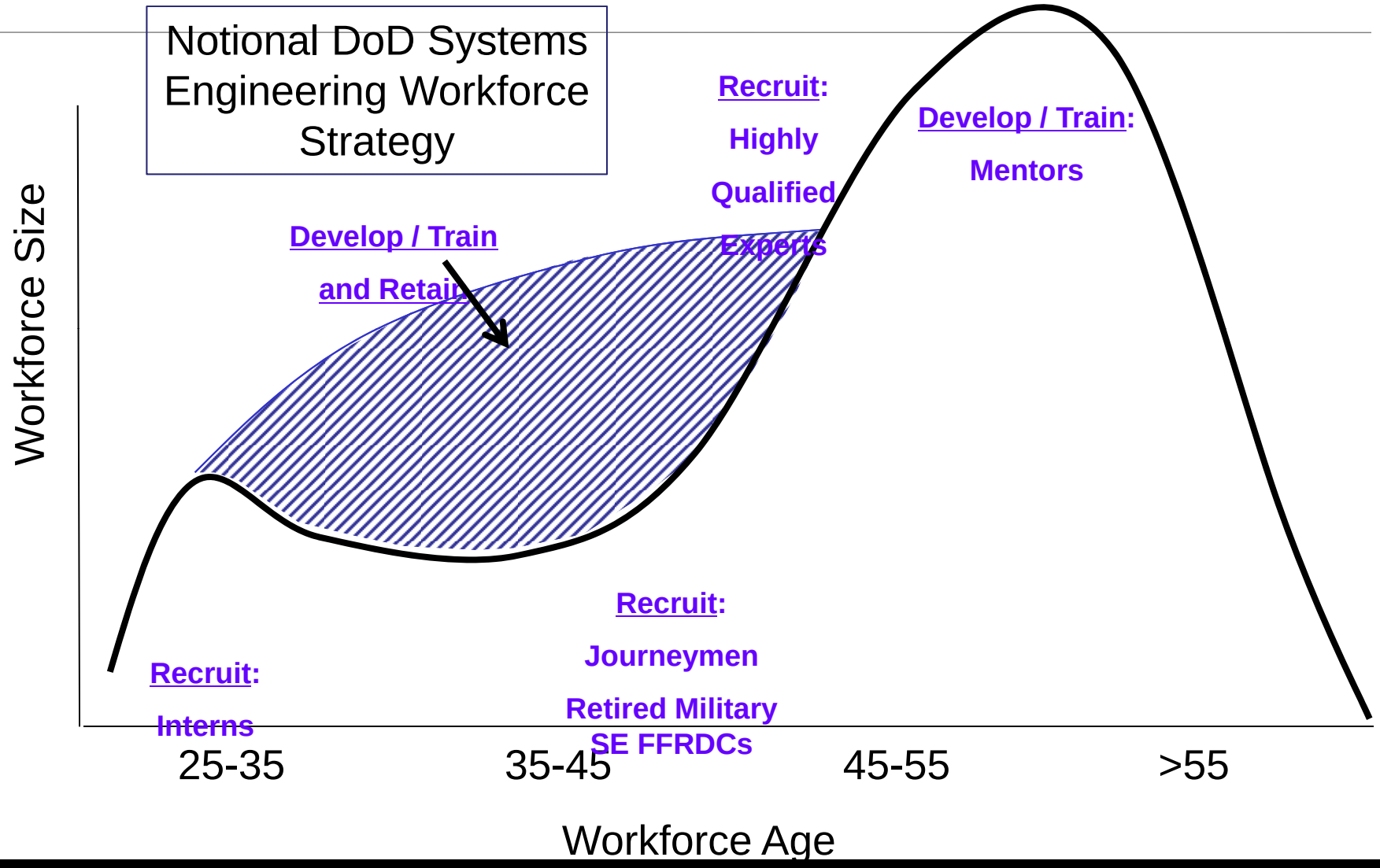
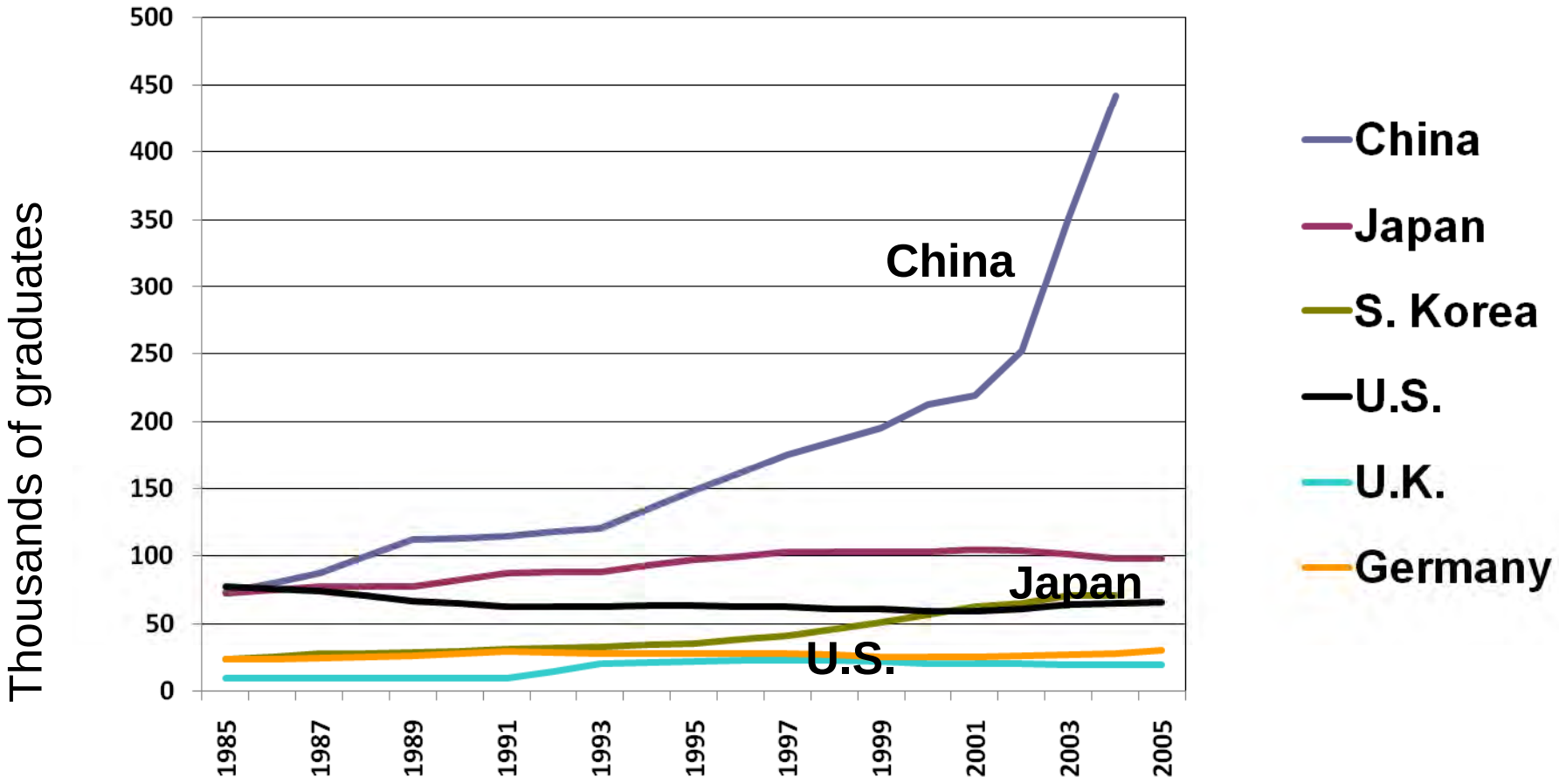


Human Capital: We are in a Competition for the Best Technical Talent



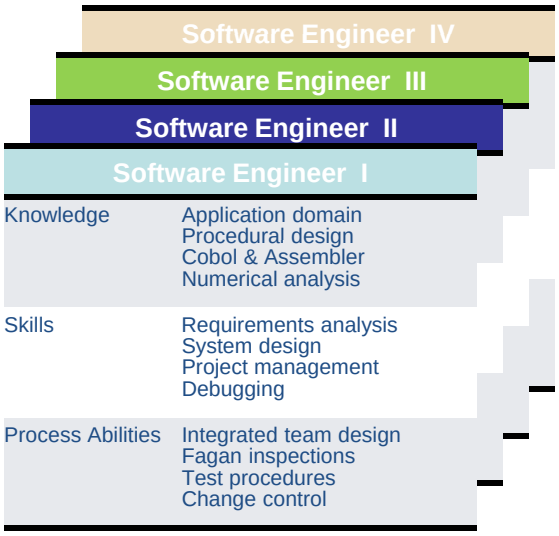
S&E Indicators, 2008

Source: The Honorable Zachary J. Lemnios

Director, Defense Research and Engineering

Human Capital: Using Core Competencies

- Accurate identification of required competencies are important to support the curriculum review and development effort needed to ensure the best and most relevant training.



Competency Family
Software Engineering

Current Resource Profile (initial inventory)

Workforce Competency	Staffing by Capacity Level			
	I	II	III	IV
Software Engineer	17	25	12	5
User Training	2	8	4	1

Current Resource Needs (one-year cycle)

Workforce Competency	Current Staffing Level Needed			
	I	II	III	IV
Software Engineer	23	30	15	7
User Training	4	9	6	2

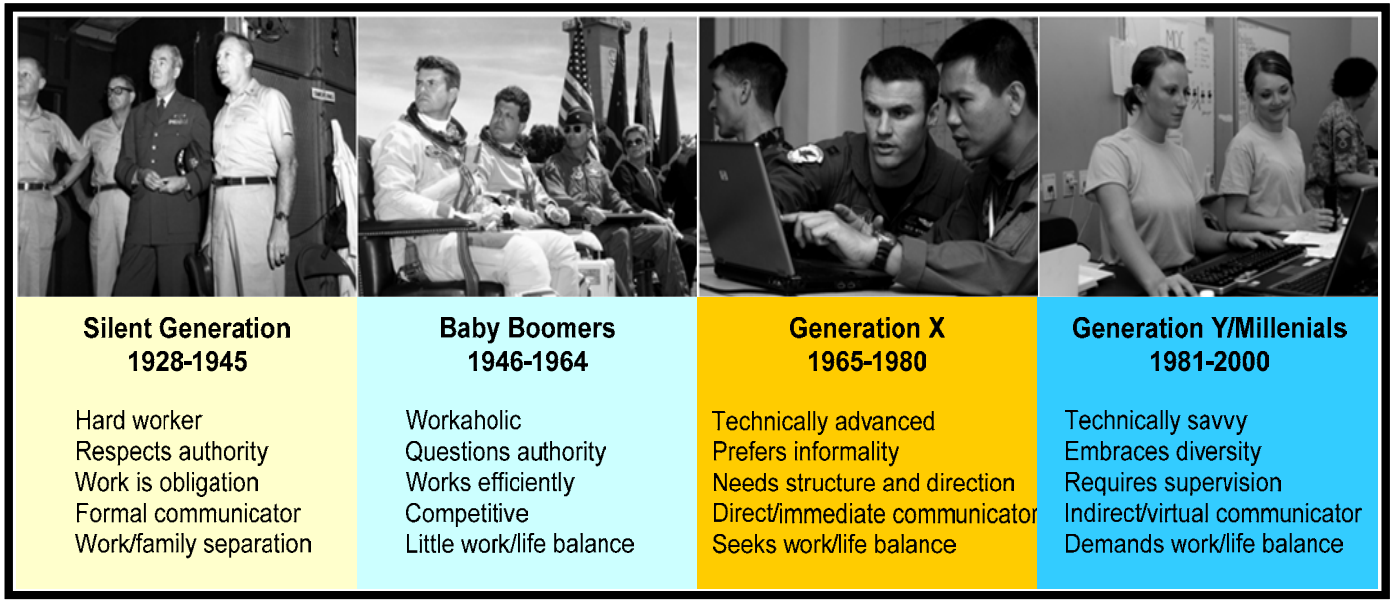
Strategic Workforce Needs (2-5 year)

Workforce Competency	2010Staffing Level Needed			
	I	II	III	IV
Software Engineer	31	35	18	9
User Training	4	10	8	3

Human Capital: Changing Demographics

Demographics of workforce are changing and different views may emerge with four generations to consider

Generation Y professionals entering workforce will likely necessitate non-traditional training techniques, such as virtual approaches



In the Current Cyber Environment, We Must Fully Engage the Software/Systems Engineering Workforce

- **Complexity**
  - Scope & Scale: number and diversity of elements
  - Connectivity: interdependencies among the disparate elements
  - Emergent behaviors: nonlinear stochastic response functions
  - Effects of non-technical attributes and characteristics
- **Criticality**
  - Systems to be continuously available
  - Able to deal with Security, Privacy, Authenticity, Accuracy, requirements "seamlessly" & without performance degradation
- **Compatibility**
  - Integrate the newest/fastest with the oldest/slowest
- **Chronology**
  - "Idea" to "IOC" measured in weeks/months versus years/decades
- **Competency**
  - Can the workforce develop the knowledge and abilities to adapt & survive?

Source: DDR&E

Questions?